Monitoring the AIDS epidemic using HIV prevalence data among young women attending antenatal clinics: prospects and problems

Basia Zaba, Ties Boerma and Richard White

February 2000

Carolina Population Center
University of North Carolina
at Chapel Hill
123 W. Franklin Street
Suite 304
Chapel Hill, NC 27516
Phone: 919-966-7482
Fax: 919-966-2391
measure@unc.edu
www.cpc.unc.edu/measure

Collaborating Partners:

Macro International Inc.
11785 Beltsville Drive
Suite 300
Calverton, MD 20705-3119
Phone: 301-572-0200
Fax: 301-572-0999
measure@macroint.com

John Snow Research and Training Institute
1616 N. Ft. Myer Drive
11th Floor
Arlington, VA 22209
Phone: 703-528-7474
Fax: 703-528-7480
measure_project@jsi.com

Tulane University
1440 Canal Street
Suite 2200
New Orleans, LA 70112
Phone: 504-584-3655
Fax: 504-584-3653
measure2@tulane.edu

Funding Agency:

Center for Population, Health
and Nutrition
U.S. Agency for
International Development
Washington, DC 20523-3600
Phone: 202-712-4959

WP-00-18

The research upon which this paper is based was sponsored by the MEASURE *Evaluation* Project with support from the United States Agency for International Development (USAID) under Contract No. HRN-A-00-97-00018-00.

The working paper series is made possible by support from USAID under the terms of Cooperative Agreement HRN-A-00-97-00018-00. The opinions expressed are those of the authors, and do not necessarily reflect the views of USAID.

The working papers in this series are produced by the MEASURE *Evaluation* Project in order to speed the dissemination of information from research studies. Most working papers currently are under review or are awaiting journal publication at a later date. Reprints of published papers are substituted for preliminary versions as they become available. The working papers are distributed as received from the authors. Adjustments are made to a standard format with no further editing.

A listing and copies of working papers published to date may be obtained from the MEASURE *Evaluation* Project at the address listed on the back cover.

Monitoring the AIDS epidemic using HIV prevalence data among young women attending antenatal clinics: prospects and problems

Basia Zaba, Ties Boerma and Richard White
Final? draft 25th November 1999, BZ

Abstract

Objective: to assess the potential of antenatal surveillance data on HIV prevalence in young women as an indicator of trends in HIV incidence.

Design: Review of empirical data and problems encountered with surveillance systems, followed by modelling using cohort-component projections and micro-simulation.

Methods: Projection models are used to illustrate dynamic relationship between changes in HIV incidence and prevalence in young pregnant women. Incidence changes due to change in risk among sexually active and change in pattern of sexual debut are explored separately, and the prevalence trends in pregnant women under age 25 and those expecting first two births are described. Micro-simulation models are used to explore effect on steady-state prevalence of co-factors which affect both fertility and HIV incidence.

Results: HIV prevalence levels in young pregnant women categorized by age and by parity have different relationships to incidence levels. Age categorized prevalence data provide a reasonable indication of incidence under stable conditions, but may be very misleading if age pattern of sexual debut changes. Prevalence levels categorized by parity are a reliable guide to incidence in the sexually active, but not necessarily to incidence in the community as a whole.

Conclusions: Ante-natal surveillance systems should categorize prevalence data by both age and parity to aid in the interpretation of underlying incidence levels.

Keywords

HIV prevalence, HIV incidence, Sentinel surveillance, Population-based surveys, measurement bias

Introduction

Reliable data on HIV incidence are essential for monitoring the spread of HIV and for assessment of the impact of sexual health interventions. Unfortunately, HIV incidence data are difficult and costly to collect and therefore limited to localized cohort studies. At the national and sub-national levels HIV prevalence data will continue to be the main source for monitoring the epidemic and assessment of the impact of interventions to reduce HIV transmission. Several methods have been used to estimate HIV incidence from prevalence data from a single survey or from multiple survey rounds by making assumptions about constant incidence rates, steady state conditions, and mortality rates among diseased subjects [1-4].

Prevalence data may be collected in population-based surveys or from sentinel or target populations. Women attending antenatal clinics are the predominant source of HIV prevalence data in most countries with generalized epidemics, especially in sub-Saharan Africa. Many countries have data on trends in HIV prevalence among antenatal women [5]. The extent to which HIV trends among antenatal women reflect trends in the general population depends on the severity of a number of biases. If antenatal attendance is high, as in most countries of sub-Saharan Africa, women attending antenatal clinics are likely to be typical of all pregnant women. However, the representativeness of pregnant women for the general female population of reproductive ages has been challenged - partly because of lower fertility in HIV infected women and partly because of selection for sexual activity [6]. Comparison of HIV prevalence between antenatal clinic and population-based samples in six African studies showed that antenatal women have lower HIV prevalence than the general female population in all age groups except the youngest (under 20 years).

HIV incidence and prevalence trends among young women are of particular relevance for monitoring of the AIDS epidemic. First, the dynamics of the HIV epidemic in young women have a very large influence on the overall course of the epidemic, because young women are a high proportion of the total population. Second, in several populations, incidence rates among young women are among the highest observed [7, 8]. Third, young women may be more likely than older women to respond to interventions with changes in behaviour. For example, declines in HIV prevalence among young antenatal women in Uganda have been attributed to behavioural change and possibly to interventions [9, 10]. Finally, effects of HIV-associated reduction in fertility or increases in mortality are likely to be less pronounced among recently infected young women. By focusing on younger individuals fewer assumptions have to be made in order to estimate incidence from prevalence and hence the incidence estimates may be more robust [11].

For these reasons, HIV prevalence among 15-24-year-old women attending antenatal clinics has been selected as one of the key indicators for monitoring HIV prevention programmes [12, 13]. Some authors have even suggested that sentinel surveillance should focus on narrower age groups of young women, such as 15-19 years [10] or 18-21 years [14].

This paper investigates whether and how data on HIV prevalence among young women from antenatal clinics could be used to estimate trends in HIV prevalence and incidence in the general

female population. In particular, the advantages and limitations of age-based measures (15-19 and 15-24 years) are assessed. Biases may occur related to age reporting, sexual behaviour, contraceptive use, and fertility. Parity-specific HIV prevalence avoids some of the reporting biases associated with age and is discussed as an additional method to age-based prevalence measurement in antenatal clinic settings. Models are used to assess the robustness of the different measures, both in rapidly evolving epidemics and in steady-state conditions.

HIV prevalence by age

Table 1 summarizes data on HIV prevalence and incidence among women in selected antenatal care and population-based studies in sub-Saharan Africa. The first two panels of this table show prevalence data broken down by age groups 15-19, 20-24, 15-24 and 25-49 years. HIV prevalence among young women varies considerably between studies, and the variation is larger at ages 15-19 than in the 20-24 age group. In several antenatal studies HIV prevalence exceeds 20% among women 15-19 years. The difference in HIV prevalence between women 15-19 and 20-24 is much larger in the population-based surveys than in the antenatal care group, because at 15-19 pregnant women are less representative of their age group than at 20-24, since the 15-19 age group contains a large proportion of women who have not yet become sexually active. The median HIV prevalence ratio 15-19 / 20-24 is 0.71 in the 17 antenatal studies (range 0.35-1.02), compared to 0.34 in the 10 population-based surveys (range 0.13-0.83).

In both sets of studies there is a strong linear relationship between HIV prevalence at 15-24 and prevalence in the reproductive ages as a whole (15-49 years in most studies), as shown in Figure 1(a). Regression lines indicate that correlation is stronger in antenatal studies than in population based studies (r^2 = .96 and .88 respectively), and that the relationship is closer to simple proportionality in antenatal studies (regression intercepts = 0.0 and 1.1 percentage points respectively). This may be due to transient incompatibility of experience in younger and older women in the cross-sectional measures: prevalence levels at ages 15-24 reflect only recent incidence rates, prevalence in the age range 15-49 is the result of exposure to historical and recent incidence. The population based data in Figure 1 are derived from communities with a mixture of old and new, rapidly growing and almost stable epidemics, so differences between age group experience will be quite variable. By contrast, antenatal data generally represent prevalence due to recent infections, since at longer durations of infection women become less fertile and thus less likely to present at antenatal clinics [15].

Figure 1(b) shows that prevalence measures in the 15-19 age group are not as strongly correlated to all age prevalence measures (r^2 = .86 and .75 in antenatal and population based studies respectively) than the corresponding relationships in the 15-24 age group illustrated in Figure 1(a); also the relationships are not as close to simple proportionality, with larger regression intercepts (2.0 and 3.4 respectively).

The last panel of Table 1 shows incidence data from the few available longitudinal community based studies, classified by age as in the first two panels. It is clear that incidence at 15-24 is

appreciably higher than in the population as a whole, but the relationship to all age incidence is reasonably proportionate, with a correlation coefficient close to one (r2 = .94) and a small regression intercept (0.3). This relationship is stronger than the corresponding relationship in the 15-19 age group (r2 = .88, intercept 0.7). Direct comparisons between prevalence and incidence measures for the same population would tell us much about the predictive power of prevalence data from young women as a measure of incidence, but published data do not allow this – in particular, it is only for Blantyre in Malawi that we have both antenatal clinic prevalence measures as well as data on incidence.

More than half of all women in the childbearing ages are in the age group 15-24 (table 1); the median proportion is 57% (range 28-67%) in the 17 antenatal care studies and 53% (range 41-66%) in the 10 population-based surveys. There is however considerable variation in the proportion of women 15-19 relative to 20-24. At the low end, only 22% of antenatal women 15-24 in Rwanda were aged under 20 years. At the high end, more than half of antenatal women 15-24 were under 20 years in Fort Portal, Uganda. Differences in age at first pregnancy are likely to be important determinants of this proportion. As HIV prevalence increases rapidly in the early phase of sexual activity, fluctuations in the age composition *within* the age groups 15-19 or 15-24 will affect the overall prevalence estimate: the younger the sample, the lower the prevalence in the age group, but virtually no studies provide data by single years of age.

HIV prevalence estimates by single-year age group, however, do not appear a feasible option. The prohibitive costs of the large samples needed to obtain sufficient numbers by single years of age make it necessary to work with larger age groups. Hitherto, most HIV sentinel surveillance clinics aimed to have samples of about 300-500 women in all age groups in a calendar year. To monitor trends in HIV prevalence an adequate number of women need to be included, as fairly large numbers of women are required to detect significant changes. For example, slightly over 1,000 women are required to be 80% confident of being able to detect a decrease from 10% to 7% at the 95% level of significance (not taking into account a design effect). For the prevention indicator (HIV prevalence among 15-24-year-olds) WHO recommended a sample size of 3,000 women in the age group 15-24 years to monitor HIV trends [12].

Age misstatement is common in countries where the respondents do not know their exact birth date. The effects of age misstatement are more serious if smaller age groups are used. Heaping on 20 years of age can be considerable and could have an effect on prevalence monitoring, especially if 15-19 and 20-24 age groups are separated. Also young pregnant women may report an older age at the antenatal clinic, especially if there is popular concern about early pregnancies, e.g. due to reproductive health interventions aimed at reducing adolescent pregnancy. This bias may be more serious for premarital pregnancies.

Another issue is the choice of a lower cut-off point for the age range. Most antenatal care clinics and population-based surveys report data from age 15 onwards. In some countries HIV prevalence data are reported separately for girls under 15 who attend antenatal clinics. In 1977 in South Africa, HIV prevalence was 9.5% among 42 pregnant girls under 15, however they constituted only 0.7% of all antenatal women under 25 [16]. In Malawi in 1977, no pregnant girl under 15 was HIV positive and girls under 15 accounted for 0.5% of all antenatal women under

25 years [17]. Population-based studies that have included girls under 15 years have generally found HIV prevalence rates of less than 1 percent (e.g. in Rakai, Uganda [18], and in Addis Ababa, Ethiopia, [11], with the exception of Rwanda in 1997, where a prevalence of 4.0% was reported in the 12-14 age group [19]. Inclusion of 12- and 14-year-olds would have a major depressing influence on prevalence in the age group described as "under 20 years", as most of them are negative (in fact, most are not yet sexually active) and because younger girls are more numerous than older ones. Therefore, exclusion of women under 15 in monitoring HIV prevalence is justified for most populations.

HIV prevalence by parity

Most antenatal clinics routinely collect data on the rank order of the pregnancy and often such data are also reported in HIV sentinel surveillance, but rarely analyzed. Pregnancies can be ranked by a woman's parity (number of previous live births) or gravidity (number of previous pregnancies), so that it should be possible to obtain HIV prevalence categorized by parity or gravidity. In Malawi in 1997, women at their first and second pregnancy represented 50.7% of the total sample and HIV prevalence among these women was 20.6%, compared to 20.4% among women aged 15-24 [17]. HIV prevalence peaked at the second pregnancy. Table 2 shows that this is typical for most settings where such data have been analyzed.

Figure 1 indicates that the proportionate relationship between prevalence in all pregnant women and women experiencing their first or second pregnancy is somewhat weaker than the corresponding relationship for the age based measure, due to the relatively wide scatter of points in populations with low HIV prevalence.

Ideally, a pregnancy history should include previous abortions, stillbirths and live births. Often, however, abortions are underreported and since many women tend to make their visit to antenatal clinics late in pregnancy (usually in the second trimester) pregnancies that lead to abortion are completely missed. In non-contracepting populations, the birth order or parity of a young pregnant woman would tend to be a more precise measure of her sexual exposure than her age, especially if there is wide variation in the age at first sex, or if initial sexual contacts are sporadic and infrequent. As a measure of length of exposure to unprotected sex, gravidity would be even more precise, as this accounts for the number of abortions as well. But in view of the reporting problems inherent in classifying women by gravidity, data classified by parity would be more robust.

Population-based sero-surveys may also classify women by parity, although the figures are not strictly comparable to the antenatal clinic data since antenatal women are closer to progressing to the next parity (they are pregnant) than women in a community survey (the proportion of women pregnant at the time of the survey is usually small). Also, the population-based data will include women who will never progress to the next parity, either because of secondary sterility or due to their partnership circumstances – these women are completely missed in antenatal HIV surveillance.

Table 1 also shows incidence data from the few available longitudinal community based studies, classified by the same age intervals as used for prevalence in the first two panels. These data are also plotted in Figure 1. Although only five data points are available, they do suggest a simple proportionate relationship between incidence at 15-24 and incidence in females of reproductive age. It is clear that incidence at 15-24 is appreciably higher than in the population as a whole.

Modelling time trends in incidence and prevalence

A simple projection model has been constructed to study the expected relationship between prevalence and incidence measures in young women when incidence changes over time. This model predicts prevalence in all women 15-24, as well as in pregnant women, and allows us to look at the effects of classifying pregnant women either by age or by parity. The equations formally defining the model are given in appendix A, and a brief, non-technical explanation of its main features follows.

The simulated population represents females aged 10 to 29 followed for 25 years from the baseline calendar year, distinguishing single year age groups and time periods. The population is assumed to arise from birth cohorts growing at 2% per year, and adult mortality from non-HIV causes is assumed to be 0.5% p.a. at all ages – under these initial conditions, one five year age group is about 13% larger than the next one. At the baseline the prevalence of HIV is assumed to be zero, but non-zero incidence among the sexually active is allowed to start within the first projection year. HIV incidence among the sexually active is assumed to be independent of age, but is allowed to vary by calendar year. Incidence is measured as an annual risk for those currently HIV negative, prevalence is a cross sectional measure with HIV positive and negative in the denominator.

The cumulated risk function describing the start of sexual activity by virgins in a given calendar year is assumed to have the form of a logistic curve, whose location and slope can be varied. The default pattern, which is assumed to have been operating up to and including year zero in the simulations shown below, stipulates that 1% of women have become sexually active by age 12, and 99% have become sexually active by age 17. The cohort pattern of sexual debut is allowed to change over time, but once a woman has become sexually active she remains so until we lose sight of her when she reaches the age of 30.

The sexually active are assumed to have a fixed annual risk of giving birth which is independent of age – in the simulations below the annual risk is 30%. This means that the parity distribution of a cohort is determined only by the distribution of the women by time since sexual debut. The simulations below do not assume any differences in risk of giving birth between the HIV negative and the HIV positive.

The main input assumption driving the model is the annual rate of HIV incidence among the sexually active, but the pattern of sexual debut, which determines the proportion sexually active

by age is also an important determinant of overall incidence and prevalence. If sexual debut is early, incidence among women aged 15-24 is virtually the same as incidence among the sexually active; if it is late, incidence in the population aged 15-24 is lower than in the sexually active as there are significant proportion of virgins in this age group.

Various measures of prevalence have been computed for this simulated population: prevalence in the population aged 15-24 is equivalent to a measure for the whole community. Prevalence measures in pregnant women aged 15-24 and aged 15-19 are equivalent to antenatal surveillance measures classified by age. Clearly only sexually active women can become pregnant. Prevalence measures in pregnant women parity 0 (women expecting first birth) and parity 0 & 1 (those expecting first or second birth) are equivalent to antenatal surveillance measures classified by parity. These parity based measures extend across the whole of the simulated age range (10 to 29), and are not confined to the 15-24 age group in which community based incidence and prevalence are measured.

This projection model is used to assess how well trends in HIV prevalence among young antenatal women correlate with HIV incidence trends if changes occur in the age at sexual debut and in the risk of HIV transmission. The various scenarios show the time lag between incidence and prevalence changes, the difference in HIV prevalence trends among all women 15-24 and among pregnant women 15-24, and the sensitivity of age- and parity-based HIV prevalence to changes in age at sexual debut and HIV incidence.

In all three projections shown below, HIV incidence among the sexually active is assumed to rise linearly from year zero, then flattens out at 5% in year 5. In scenario 1 (figure 2a) it falls linearly from year 15, reaching a level of 2% in year 18. (Incidence in the sexually active population and incidence in the 15-24 age group coincide exactly in this simulation, so the trend lines are superimposed throughout.) In scenario 2 (figure 2b) incidence among the sexually active remains constant at 5% for the rest of the projection period, but the pattern of sexual debut is assumed to age rapidly between calendar years 10 and 13, so that after year 13, the age by which 1% have become active has risen from age 12 to age 16, the age at which 99% have become active has risen from 17 to 24. The last scenario (figure 2c) shows the effect of combining a fall in incidence among the sexually active (as in the first scenario) with a rise in age of sexual debut (as in the second scenario).

In scenario 1, trends in the community based prevalence measure for ages 15-24 are echoed closely by trends in prevalence among pregnant women aged 15-24, and by trends for those experiencing first and second births. Trends in prevalence among 15-19 year olds follow a broadly similar pattern, but at a lower overall level. All the pregnant women based prevalence measures as well as the community based measure respond immediately to the decline in incidence rates among the sexually active which starts in year 15. However, there are lags in the responses to the levelling off in incidence, both after the period in which incidence was rising (up to year 5) and after the period of decline in incidence (years 15 to 18).

The reason for these lags is that it takes some time for the relevant age or parity groups to fill up with women who have been subject to the new level of risk for the whole of the time that they

typically spend in that group. That is why the lags are longest for the "by parity" grouping of pregnant women: at a constant annual risk of birth of 30% for the sexually active, about half of first births occur within 2 years of the start of sexual activity, but about 10% of second births occur to women who had been sexually active for more than 7 years.

The reason for the more-or-less instant response of all the prevalence measures to the drop in risk at year 15, is that the simulation represents a growing population, so that the youngest single-year cohort with lowest HIV prevalence, which enters observation after the fall in risk is numerically larger than the oldest cohort with the highest prevalence which leaves observation. Again, this relationship is tighter for age-based rather than parity based measures.

Figure 2b illustrates the second scenario, in which the decline in incidence that takes place after year 10 is due to a rise in the age at sexual debut. The age range in which 98% of the population is assumed to lose their virginity moves from ages 12-17 to 16-24, eventually producing a fall in incidence in the age group 15-24 from 5% to 2%, even though the risk to the sexually active does not change. Although the change in age pattern of sexual debut takes only 3 years to accomplish (as with the fall in HIV risk in the previous figure) it takes about 7 years for incidence to fall from 5% to 2%, as this is how long it takes the women who had experienced the earlier, faster rates of sexual debut to leave the 15-24 age group and be entirely replaced by women who had experienced only the later, slower sexual debut rates. The community based prevalence measure responds immediately to the beginning of the fall in incidence, but doesn't level out until about year 22, i.e. about 5 years after the community based incidence curve levels out.

The parity based measure stays at its peak values, because it reflects the steady risk experienced by the sexually active – only the sexually active become pregnant, and the distribution of the women experiencing a first birth or second birth by time since start of sexual activity does not change, although their age composition may change as sexual debut patterns change. Since prevalence among the sexually active is determined by length of exposure to sexual activity and by risk level, the prevalence curves by parity for pregnant women stay constant.

The prevalence measure in pregnant women aged 15-24 actually rises for four to five years in response to an increase in the age at sexual debut. This is because among this selected group of pregnant (and therefore sexually active) women the balance of women who have been sexually active for a relatively long time initially increases, as the incoming youngest cohorts are numerically depleted by the lower rates of entry into sexual activity. After some years, those who experienced the earlier pattern of starting sexual activity cease to dominate the age group, and the distribution of pregnant women by duration since sexual debut begins to reflect the new pattern of age at first sex. The HIV prevalence in the age groups of pregnant women then falls very rapidly, even though community incidence in the same age group is levelling off at this stage. The pattern of change in prevalence among 15-19 year old pregnant women is broadly similar to that in 15-24 year olds, but with earlier and steeper rises and falls.

Figure 2c illustrates the situation where both sexual debut changes and changes in incidence level among the sexually active occur. Overall, prevalence trends in the parity grouping of pregnant women give a truer representation of incidence trends than prevalence trends in pregnant women

categorized by age group. Changes in prevalence among pregnant women classified by parity consistently lag behind population based changes in incidence in the 15-24 age group. Trends in the age based pregnant prevalence measures have an erratic relationship to population based incidence trends, just as in the previous simulation.

However, the relationship between the interim peak level of population based incidence and the corresponding final stable incidence level (5% : 1%) is fairly accurately reflected in the approximate relationship between the peak and final values of the age-based measures for pregnant women (12% : 3% in 15-19-year-olds; 20% : 5% in 15-24). In contrast, the peak : final ratio in the parity based measure (20% to 10%) is too low, though it does reflect the ratio for incidence in the sexually active (5% : 2%).

The general conclusion which can be drawn from these illustrations is that lagged parity based measures of prevalence in pregnant women are a consistent indicator of incidence in the subgroup of sexually active women in the community. Although short-term trends in prevalence in young pregnant women classified by age can be misleading as indicators of current incidence trends, once these have been stable for some time, they should be reasonable indicators of stable incidence in the community as a whole. About five years of unchanging prevalence in the 15-24 age group of pregnant women can be taken as evidence of stability, since in this time the 15-19 age group, whose composition is most likely to be affected by changes in age at sexual debut would experience a complete turnover in membership.

Modelling determinants of infection and fertility risk

The projections discussed above were caricatures designed to alert us to the transient differences between prevalence in young pregnant women and women in general which complicate the use of prevalence data from antenatal surveillance as a guide to incidence trends in the general female population. The only explanatory factor explicitly considered was the age pattern of sexual debut. The simulations in which we allowed for a reduction in risk among the sexually active assumed that such changes would have no influence on pregnancy risks. However, some factors which influence HIV transmission risk can also affect fertility. These include some which are the subject of specific intervention strategies, such as increasing condom use and decreasing the prevalence of other STDs. The following simulations illustrate the effects of different levels of such factors on the relationship between incidence, general population prevalence and prevalence in pregnant women. Instead of tracing changes over time, we only compare populations in which incidence and prevalence have stabilised under a variety of conditions. This is equivalent to examining the evolving populations in the first three simulations only in the final “flattening out” phases of the projections.

Since a multi-state projection becomes prohibitively complex if we have to allow for too many time dependent factors simultaneously, the methodology employed here is stochastic micro-simulation. In this approach, we model the individual life-courses of women grouped into cohorts of 10,000. Each woman is followed from age 10 to age 50 (or death, whichever occurs

earlier), on a monthly basis. She is subject to (mainly empirically determined) risk schedules governing various changes of state affecting fecundity, sexual behaviour and infection. These include experience of menarche, partnership formation, conception, pregnancy outcome, disease transmission and disease progression. Average age and duration specific risks are fixed at the population level, but whether or not a particular woman experiences a change of state in any one month depends on her state as she enters that month (e.g. only a non-pregnant, fecund woman with a sexual partner can become pregnant), and on a randomly determined binomial change-of-state variable (a pseudo-random number from a uniform zero-one distribution is compared to the appropriate population risk level).

Although this model does not explicitly generate entire male life histories, assumed levels of HIV and other STD infections in the male population determine the risks of encountering an infected partner for females. The model allows us to set different prevalence levels (and corresponding incidence levels) among the population of men from whom casual and cohabiting partners are drawn. It is also possible to specify for (initially HIV negative) male partners in cohabiting unions a changing level of incidence with duration of union, to reflect a changing likelihood of their concurrent involvement with casual partners. Cofactor effects for higher transmission of HIV from an infected partner can be specified for women already infected with other STDs, as can higher risk levels for STD transmission for women who are HIV positive.

Summary statistics on the outcome of all the individual events can be compiled to represent whole cohort experience (as in a prospective or retrospective study); or in a population, by sampling the cohort at an appropriate distribution of ages (to represent cross-sectional measures); or as the women experience pregnancy (to represent an antenatal surveillance sample). The parameters governing the population level risk distributions are shown in appendix B, a more formal mathematical treatment of the simulation procedure and detailed explanation of the model is available in [20].

Four sets of simulations are discussed below. In the first, we vary the population level parameters governing the duration and re-formation of sexual partnerships and coital frequency within partnerships, distinguishing cohabiting and casual unions. This allows us to vary the exposure to risk of the sexually active, and not just entry into sexual activity and overall risk level as in the first batch of simulations. In the second simulation we examine the effects of prophylactic condom use in casual and cohabiting unions, and in the third we look at infection rates and disease duration for syphilis and the classical sterilising STDs. Finally, we examine the effect of various fetal loss rates among infected and uninfected women on HIV prevalence measures in antenatal clinics. Each simulation set consists of 8 distinct simulations and the default simulation, which appears as the central point in each figure.

Figures 3a to 3d show incidence and prevalence in the general female population 15-24, and prevalence in young pregnant women classified either by age or by parity. The difference between these graphs and figures 2a to 2c is that the x-axis does not represent time, but a measure relating to a specific risk variable. The points on the graph represent the relationships observed in distinct populations between prevalence and incidence measures and the predictor

variable. The lines represent regressions of prevalence and incidence measures against the risk determinants.

Figures 3a to 3c show that in the first three simulations prevalence in pregnant women aged 15-24 is broadly similar to prevalence in the general female population of the same age, whereas prevalence in women experiencing first and second births is a little higher. This is because in these micro-simulations we allow for discontinuities in sexual exposure (break-up and reformation of partnerships), so that it takes a little longer for women to reach their second pregnancy, and therefore a larger fraction of these women are in the age group 25 and over. This is a more realistic representation of the situation in real populations than could be achieved with the simple projection model discussed in the previous section.

An impression of the robustness of the prevalence measures as indicators of incidence can be gleaned by comparing the relative scatter of prevalence points about their regression lines compared to the scatter of the incidence points. In these first three simulations the parity based measures perform as well as the age based measures as indicators of incidence. Since point prevalence for these young women is of the order of five times the incidence rate, we would expect the slopes and intercepts of the prevalence regression lines to be consistently proportionately greater than the corresponding incidence relationships. If such consistency is not observed, this warns us that a prevalence measure may be biased if used as an indicator of incidence in comparisons between different steady state populations.

Figure 3a confirms that age- and parity-based prevalence measures in pregnant women are reasonable indicators of incidence level when comparing populations experiencing different levels of casual sex. However, community based prevalence in the 15-24 age group is more strongly affected by the extent of casual sexual activity, and would exaggerate incidence rates in this age group if used as a comparative indicator between populations.

All three prevalence measures faithfully reflect incidence levels in populations with different levels of condom use, with virtually no apparent bias, as shown in figure 3b, though the parity-based measure in pregnant women is slightly less robust. This is due to the relatively wide scatter at the lowest rates of condom use, where this measure is more sensitive than the others to the balance of use between casual and cohabiting partnerships.

From figure 3c, we can see that all three prevalence measures would tend to be lower in populations with lower incidence of other STDs. The relationship between HIV prevalence and other STD incidence is stronger than that between HIV incidence and other STD incidence, presumably because we have allowed in our models for HIV positive women to be more prone to subsequently contracting other STDs because they would have less immunity to any infectious disease.

Figure 3d shows a very different picture of the prevalence – incidence relationships. In this simulation we have varied the degree of fetal wastage due to vertical transmission of HIV, that is the excess early fetal losses and the still births experienced by the HIV positive. Differences in vertical transmission do not affect incidence (or prevalence) in the general female population.

However, even very small differences in the extent of HIV induced early fetal loss can cause quite large variation in the prevalence measures for pregnant women, particularly in the age-based measure. This is because women who suffered miscarriages in the first trimester would not be seen in antenatal clinics (in this model we assume that the first antenatal consultation takes place in the second trimester). This simulation is not supposed to represent the effect of anti-retroviral treatment for pregnant women, since this would typically be given late in pregnancy and would therefore only affect the still birth rate not early fetal losses. Rather it is an attempt to examine the possible effects of other factors which might enhance vertical transmission in some populations – e.g. vitamin A deficiency or high malaria prevalence. It is worth noting, that in cross regional comparisons, we would encounter similar biases if women were consistently seen at an earlier stage of pregnancy in clinics in one place than in another, as the earlier in pregnancy a woman comes to the antenatal clinic, the more likely she is to be seen, and her HIV status measured before she miscarries.

Table 3 presents a summary goodness of fit statistic, showing how well the different prevalence measures illustrated in figures 3a to 3d would perform as indicators of population incidence at ages 15-24 under the assumption of simple proportionality. The goodness of fit is a chi-squared measure, obtained by summing the squares of the proportionate differences between the predicted and actual incidence values in the model, when each of the four determinants discussed above is allowed to vary. Clearly, the community based prevalence measure is a much better predictor of incidence in young women than any of the measures based on prevalence in pregnant women. The measure based on prevalence in 15-19-year-old pregnant women is by far the least satisfactory predictor, with much higher chi-squared values than all the others. The estimates based on prevalence among pregnant women delivering their first or second births perform almost as well as those based on prevalence in pregnant women aged 15-24 for three out of the four determinants considered (coital frequency, condom use, and co-infection with other STDs). However, the parity based measure clearly outperforms the age based measure when the scale of fetal losses due to HIV is allowed to vary between populations, so that the overall chi-squared score over all 32 simulation runs is lower for the parity based predictor.

Discussion

The simulations and projections above have shown that for antenatal clinic based HIV prevalence estimates to be useful as predictors of incidence among young women, the age group used should be wide (15-24 rather than 15-19) and that it is useful to collect parity based data to complement the age based data. As indicators of incidence, age based estimates and parity based estimates are subject to slightly different biases. Parity-based indicators are better at reflecting the dynamics of infection in the sexually active population, but age-based measures may be better at portraying incidence levels in young women as a whole.

All the prevalence measures lag behind changes in incidence, but age-based prevalence measures in pregnant women may be additionally subject to rapid fluctuations if there are significant changes in the age at sexual debut. This is due to changes in the composition of the age group by

time since sexual debut. These prevalence fluctuations in young pregnant women may give the impression that incidence is rising when it is in fact falling, or may give the impression that a very rapid decline is occurring when the pace of the incidence decline due to later sexual debut is quite moderate. However, these effects are transitory, and the stable prevalence level eventually attained in pregnant women aged 15-24 should be a reasonable guide to the stable incidence level in this age group. Comparisons with trends in prevalence among women expecting their first and second births could alert us to spurious transient prevalence trends in the age-based measure, as the parity based measure should be very little affected by changes in age at sexual debut.

With respect to those determinants of changes in infection probability among the sexually active which we have investigated: coital frequency, condom use, and co-infection with other STDs, both the parity-based prevalence measure, and the measure based on prevalence among 15-24-year-old pregnant women perform reasonably well, but prevalence in pregnant 15-19-year-olds is a relatively poor predictor of incidence in 15-24-year-old women. Parity based measures are less affected by inter-population differences in fetal mortality due to vertical transmission of HIV – this is not, of course, a determinant of incidence, but merely another nuisance factor which needs to be taken into account when comparing prevalence levels in pregnant women in different populations.

In a few countries empirical data on HIV prevalence among women attending antenatal clinics have shown that prevalence declines are likely to occur first in the younger antenatal women. For example, in Uganda, such trends were observed from about 1993 [9, 10]; in Chiang Rai, Thailand, HIV prevalence fell markedly among young childbearing women from 1994 [21]. If such changes occur, careful consideration needs to be given to a number of biases. These include changes in the quality of data collection and HIV testing, utilization of antenatal care (by younger women), and biases related to selection for sexual activity and HIV-associated reduction of fertility [6]. At the national level the selectivity of antenatal HIV sentinel surveillance sites may also present a problem. In most countries rural sites are severely underrepresented.

HIV trend data from other population groups can provide important evidence to support the observed trends in antenatal women. In Uganda, HIV incidence and prevalence trends from population-based cohort studies provided some support for the trends in young antenatal women [22, 23]. In Thailand, a multitude of data source documented a decline in HIV prevalence [24-26]. The Thai data also indicated a decline in the incidence of other STDs [27].

From the programme evaluation perspective two important questions follow the observation of a decline in HIV prevalence among younger antenatal women. The first question concerns the extent to which such changes can be attributed to changes in sexual behaviour. If such changes occur, the second question can be posed; to what extent can changes in sexual behaviour be attributed to interventions? In Uganda, survey data on sexual behaviour [9] and modelling [10] were used to assess whether behavioral changes may have caused the decline in HIV prevalence. In Thailand, a very large number of behavioural surveys showed a rapid decline in visits to female sex workers and an increase in condom use [24, 27]. Programme output statistics in both Uganda and Thailand suggested that some of the behavioural changes were associated with interventions.

Our analysis and simulations show that HIV prevalence trends among young antenatal women are a fairly good indicator of HIV incidence trends in most circumstances. A wide age interval should be used (15-24) rather than five-year age groups and monitoring HIV trends by parity 0 and 1 further enhances the ability of antenatal data to describe true trends. The results strongly suggest that surveillance of the epidemic and monitoring and evaluation of interventions will greatly benefit from a renewed and concerted effort to obtain reliable data on HIV prevalence trends among young women in antenatal clinics at national and sub-national levels [13].

Appendix A: the projection model

In general, the population aged *a+1* at time *t+1*, $P(a+1,t+1)$ is derived from the population aged *a* at time *t*, by considering the action of all decremental forces, $q_i(a,t)$, which might remove women from the cohort. All the forces governing movements between population groups are assumed constant within a single year, so that we can write:

$$P(a+1,t+1) = P(a,t)\exp\left[-\sum_i q_i(a,t)\right]$$

Since we are considering a relatively narrow age range of women, we have assumed the force of mortality from causes other than HIV, m^o, to be the same for all ages and unchanging over time. The force of mortality due to HIV, $m^h(d)$, is assumed to depend only on duration since infection, d.

Subgroups of the population may be subject to decremental forces other than mortality, in particular, the number of virgins, $P^v(a+1,t+1)$, is given by:

$$P^v(a+1,t+1) = P^v(a,t)\exp[-m^o - s\,(a,t)]$$

where $s\,(a,t)$, is the force of sexual initiation at age a and time t.

The number of HIV negative, sexually active women $P^s(a+1,t+1)$, is thus:

$$P^s(a+1,t+1) = P^s(a,t)\exp[-m^o - h(t)]$$
$$+ P^v(a,t)\exp[-m^o - h(t)/2]\times\{1-\exp[s\,(a,t)]\}$$

where $h(t)$ is the force of infection among the sexually active at time t, assumed to be independent of age.

The number of newly infected women, $P^h(a+1,t+1,0)$, is:

$$P^h(a+1,t+1,0) = P^s(a,t)\exp[-m^o]\times\{1-\exp[-h(t)]\}$$
$$+ P^v(a,t)\exp[-m^o]\times\{1-\exp[s\,(a,t)]\}\times\{1-\exp[-h(t)/2]\}$$

and the number of HIV positive women infected *d+1* years ago, $P^h(a+1,t+1,d+1)$, is:

$$P^h(a+1,t+1,d+1) = P^h(a,t,d)\exp[-m^o - m^h(d)]$$

The total number of HIV positive women, $P^h(a,t)$, is obtained by summing across all duration groups:

$$P^h(a,t) = \sum_d P^h(a,t,d)$$

We have also assumed that the sexually active are subject to a constant fertility force f, so that the proportion $f^b(a+1,t+1)$ of sexually active women remaining at the same parity, b, from one year to the next is:

$$f^b(a+1,t+1) = f^b(a,t)\exp[-f]$$

Since f is independent of age, achieved parity will depend only on duration since sexual debut. Assuming that women cannot experience more than one birth per year, the proportion of women *d* years after sexual debut at parity *b*, $F^b(d)$, is:

$$F^b(d) = f^b(a,t)\exp[-f]$$

We have assumed that the initial population is quasi stable, so that with a growth rate, *r*, the initial structure can be defined using:

$$P(a+1,0) = P(a,0)\exp[-m^o - r]$$

and the number of new 10-year-old entrants each year, $P(10,t)$, is given by:

$$P(10,t+1) = P(10,t)\exp[r]$$

Appendix B: Simulation variants with parameter ranges and outcome measures used for sensitivity analysis in micro-simulation model

Simulation set and parameters	Range	Tabulated outcome measures and notes on parameters
HIV transmission risks		**Life time risk of HIV**
Prevalence in casual partners	10% - 40%	Prevalence in cohabiting partners is assumed to be half that in casual partners. Male prevalence is an exogenous variable in this model.
Prevalence in cohabiting partners	5% - 20%	
Per coitus transmission risk	0.002 - 0.004	Average per-coitus transmission risk will change depending on the proportion of males who are in the primary stage of infection
Sexual debut		**Mean age at first sex**
Earliest age at first sex	11 – 15 years	
First sex build up, start to mean	2 – 6 years	
Union turnover		**Lifetime casual partners**
Max risk of union re-formation	0.06 – 0.24	Monthly rate for union re-formation at peak age
Casual union proportion	0.6 – 0.9	Peak proportion, declines with age
Coital frequency		**Lifetime casual sex acts**
At start of cohabiting union	0.7 – 0.3 / day	
At start of casual union	0.7 – 0.1 / day	
Condom use, mainly in casual partnerships		Prevalence of condom use by sexually active
Proportion of FPs using condoms	10% - 90%	Same method mix applied to FP users in all unions
Use in casual partnerships	1% - 90%	Scale of use varied from 10% default only in casual partnerships

Simulation set and parameters	Range	Outcome measure and notes on parameters
General FP use, mainly in cohabiting partnerships		**Contraceptive prevalence for sexually active**
Post-partum cohabiting use	10% - 50%	
Duration of use post-partum	1.5 – 5.0 yrs	Only in cohabiting unions
Gonorrhea and Chlamydia		**Lifetime risk of one or more episodes**
Prevalence in casual partners	5% - 20%	Prevalence in cohabiting partners is assumed to be half that in casual partners.
Prevalence in cohabiting partners	2.5% - 10%	
Per coitus transmission risk	0.03 – 0.3	

Syphilis		**Lifetime risk of one or more episodes**
Prevalence in casual partners	5% - 20%	Prevalence in cohabiting partners is assumed to be half that in casual partners.
Prevalence in cohabiting partners	2.5% - 10%	
Per coitus transmission risk	0.03 – 0.3	
HIV mortality consequences		**Proportion of deaths due to AIDS**
Mean time infection to AIDS	8 - 12 years	Exponential distribution of progression
Excess mortality HIV+ pre-AIDS	100% – 300%	Mortality before developing AIDS symptoms
Fetal loss and HIV stillbirths		**(Still births + Fetal deaths) / pregnancies**
Fetal death multiplier for HIV	100% – 500%	
Still birth multiplier for HIV	100% – 500%	

Table 1: HIV prevalence and incidence among women by age and data source

HIV Prevalence

		Age group											
Data Source		15-19		20-24		15-24		25-49		all women		exceptions	
		%	n	%	n	%	n	%	n	%	n		
Ante Natal Clinic													source
Blantyre, Malawi	1994-95	24.1	1691	37.0	2460	31.7	4151	27.9	2770	30.2	6921		[8]
Blantyre, Malawi	1993	24.7	543	33.3	979	30.2	1522	30.1	942	30.2	2464		[8]
Zambia, urban	1994	20.4	1147	32.2	1867	27.7	3014	28.7	2237	28.2	5251	15-44	[28]
Blantyre, Malawi	1990	22.0	1377	27.3	2111	25.2	3488	20.3	3196	22.9	6684		[8]
Bujumbura, Burundi	1991-92	12.5	287	19.0	499	16.6	786	17.2	763	16.9	1549		[29]
Butare, Rwanda	1989-91	11.2	276	13.9	1296	13.4	1572	7.9	4093	9.3	5690		[30]
Zambia, rural	1994	9.0	1446	15.2	2012	12.6	3458	13.4	2600	12.9	6058	15-44	[28]
Mangochi, Malawi	1987-90	7.5	1352	9.6	1092	8.4	2444	8.6	1509	8.5	3953		[31]
Kinshasa, Zaire	1989	2.8	722	8.1	1356	6.3	2078	6.7	2545	6.5	4623		[1]
Nairobi, Kenya	1991-93	14.4	653	14.1	1466	14.2	2119	13.1	1043	13.8	3162		[14]
Nairobi, Kenya	1994-97	13.5	821	15.9	1619	15.1	2440	16.2	1226	15.5	3666		[14]
Fort Portal, Uganda	1991-93	23.3	400	28.0	371	25.6	771	17.7	526	22.4	1297		[10]
Fort Portal, Uganda	1994-97	13.8	645	25.1	638	19.4	1283	19.2	691	19.4	1974		[10]
South Africa	1997	12.8	2107	19.7	3590	17.1	5697	15.2	6058	16.1	11755		[16]
South Africa	1996	12.7	2151	18.0	3491	16.0	5642	13.7	5916	14.8	11558		[16]
Malawi	1997	14.7	1301	23.9	2111	20.4	3412	21.2	2246	20.7	5658		[19]
Rwanda	1996	11.4	140	16.0	494	15.0	634	15.2	734	15.1	1368	15-44	[19]
Population-based													
Masaka, Uganda	1994	2.5	531	19.4	211	7.3	742	12.8	611	9.8	1353	13-44	[22]
Masaka, Uganda	1989	4.5	601	21.3	282	9.9	883	11.5	723	10.6	1606	13-44	[22]
Kisesa, Tanzania	1994-95	1.0	692	7.7	663	4.3	1355	8.6	1730	6.7	2041	15-44	[32]
Lusaka, urban	1995-96	12.3	391	35.4	311	22.5	702	40.1	509	29.9	1211	15-39	[28]
Addis, Ethiopia	1994	3.5	510	9.1	326	5.7	836	8.4	812	7.1	1648		[11]
Kapiri, rural, Zambia	1995-96	8.2	122	24.6	114	16.1	236	18.9	190	17.4	426	15-39	[28]
Rwanda, rural	1997	8.3	289	10.0	210	9.0	499	13.2	711	11.5	1210		[19]
Fort Portal, Uganda	1995	12.3	122	30.3	99	20.4	221	14.1	306	18.4	527		[10]
Mara, Tanzania	1989-90	5.1	475	12.6	548	9.1	1023	6.6	1038	7.9	2061		[33]
Kisesa, Tanzania	1996-97	2.5	651	7.7	793	5.4	1444	9.7	2041	7.9	3485	15-44	[32]

HIV Incidence

		15-19		20-24		15-24		25-49		15-49		exceptions	
Population-based													
Rakai, Uganda	1994	5.0	81	6.8	73	5.9	154	12	163	4.0	303	15-39	[7]
Blantyre, Malawi	1994-95	6.0	502	4.6	699	5.2	1201	3.2	1101	4.2	2302		[8]
Dar es Salaam	1992-95	6.5	169	3.8	737	4.3	906	2.7	1330	3.4	2236	FP	[34]
Kigali, Rwanda	1988-92	4.3	93	3.4	262	3.6	355	3.2	222	3.5	577	ANC	[35]
Kisesa, Tanzania	1994-96	0.5	754	1.4	816	1.0	1570	0.8	2510	0.8	4068		[32]
Masaka, Uganda	1990-94	0.7	1849	1.5	658	0.9	2507	0.8	2197	0.8	4704	15-44	[36]

Table 2: HIV prevalence and incidence among women by pregnancy or birth order and data source

HIV Prevalence by Gravidity

Data source		G1		G2-3		G4-5		G6+				exceptions	
		%	n	%	n	%	n	%	n	%	n		
Ante Natal Clinic													
Blantyre, Malawi	1990	25.6	1560	26.4	2177	22.9	1505	14.4	1447	22.9	6689		[8]
Blantyre, Malawi	1993	28.7	663	33.4	963	30.8	794	21.7	355	30.2	2775		[8]
Blantyre, Malawi	1994-95	29.5	2449	37.1	2083	31.6	1125	19.1	1276	30.2	6933		[8]
Butare, Rwanda	1989-91	13.0	1351	13.1	1794	5.6	1632	6.2	913	9.3	5690	G4-6, G7+	[30]
Mangochi, Malawi	1987-90	8.4	1246	8.7	951	5.4	1746			8.5	3943	G2, G3+	[31]

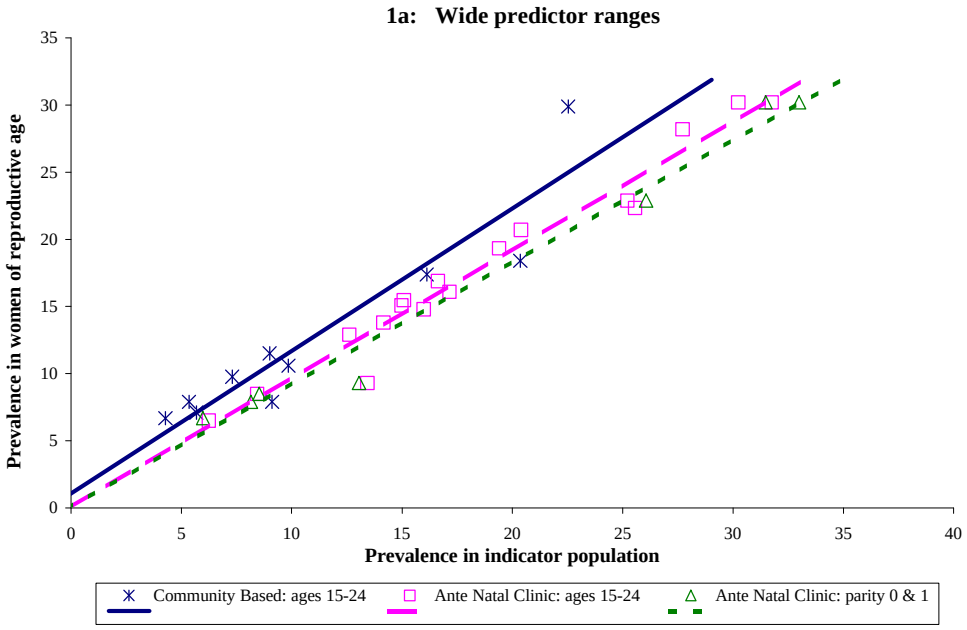
by Parity

		P0		P1		P2-3		P4+					
		%	n	%	n	%	n	%	n	%	n		
Demographic surveillance													
Kisesa, Tanzania	1994	4.3	448	7.1	675	9.2	675	6.7	1201	6.7	2999		[32]
Kisesa, Tanzania	1996	5.8	676	11.1	540	9.6	868	6.6	144	7.9	2228		[32]

Table 3
Robustness of prevalence measures as indicators of HIV incidence
(Chi-squared measures of prediction accuracy)

Determinant	Community based prevalence ages 15-24	Pregnant women prevalence ages 15-19	Pregnant women prevalence ages 15-24	Pregnant women prevalence parity 0 & 1
Coital frequency	0.07	0.43	0.06	0.08
Condom use	0.08	0.71	0.13	0.22
STD co-infection	0.05	0.45	0.05	0.07
Fetal loss	0.02	1.66	0.49	0.12
Sum of goodness of fit statistics	0.22	3.25	0.75	0.49

Figure 1 Prevalence in young women as a predictor for all age prevalence



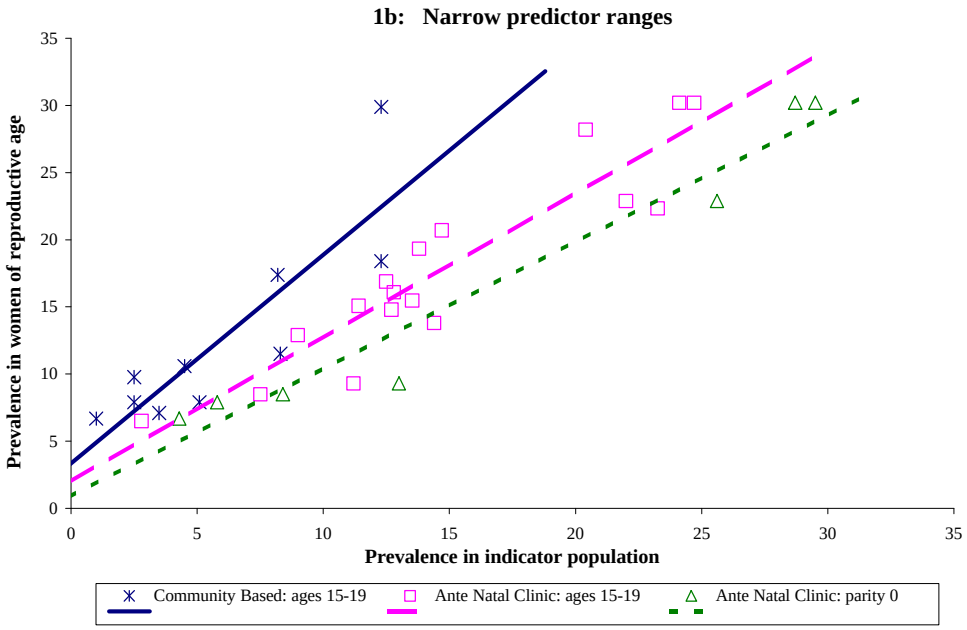


Figure 2 Prevalence and incidence trends in young women

Figure 2a: Decline in risk for sexually active

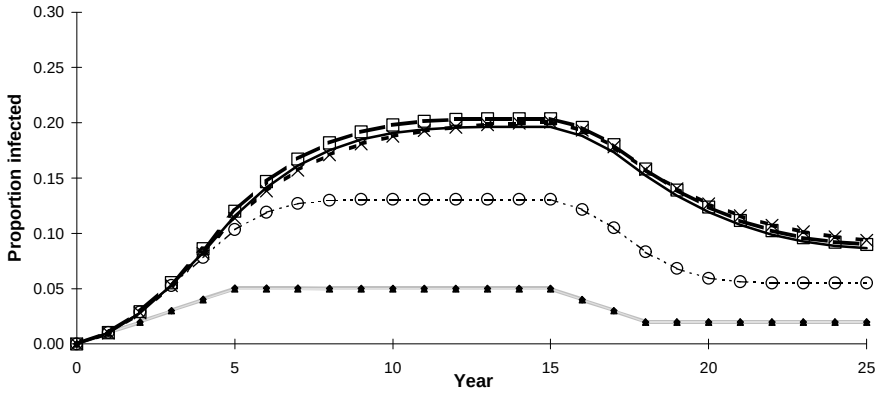


Figure 2b: Delayed sexual debut

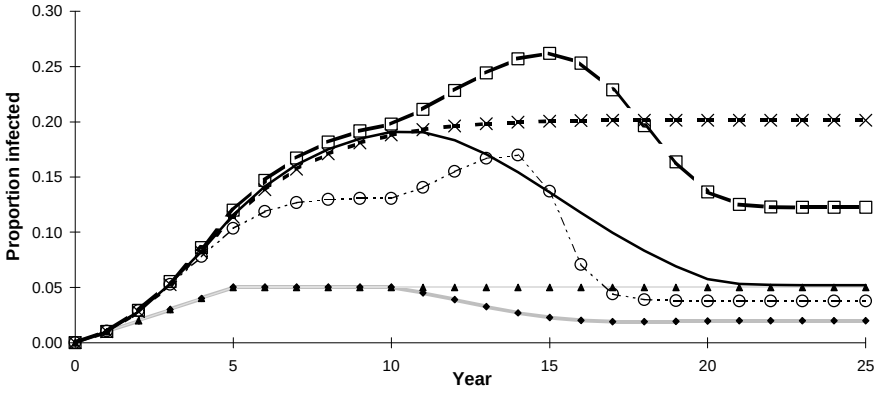


Figure 2c: Delayed sexual debut and decline in risk

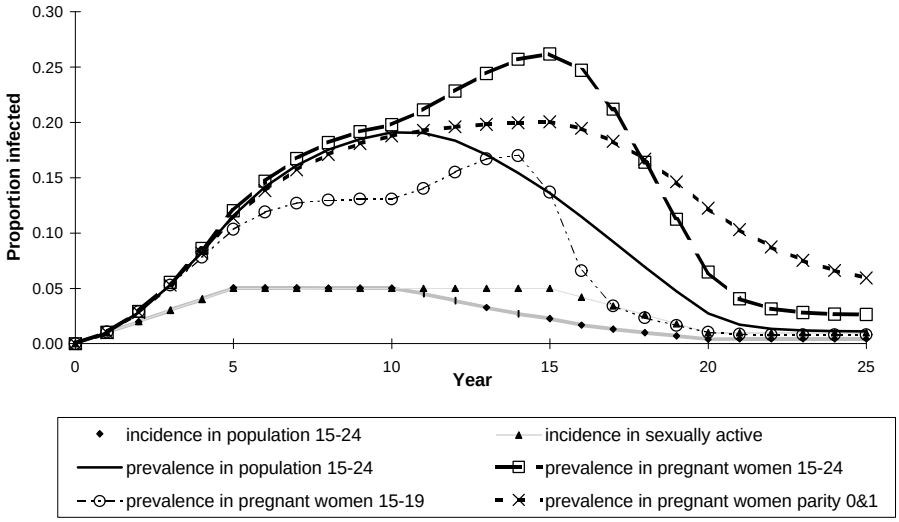


Figure 3 Determinants of HIV prevalence and incidence levels

Figure 3a: Coital frequency in casual and cohabiting unions

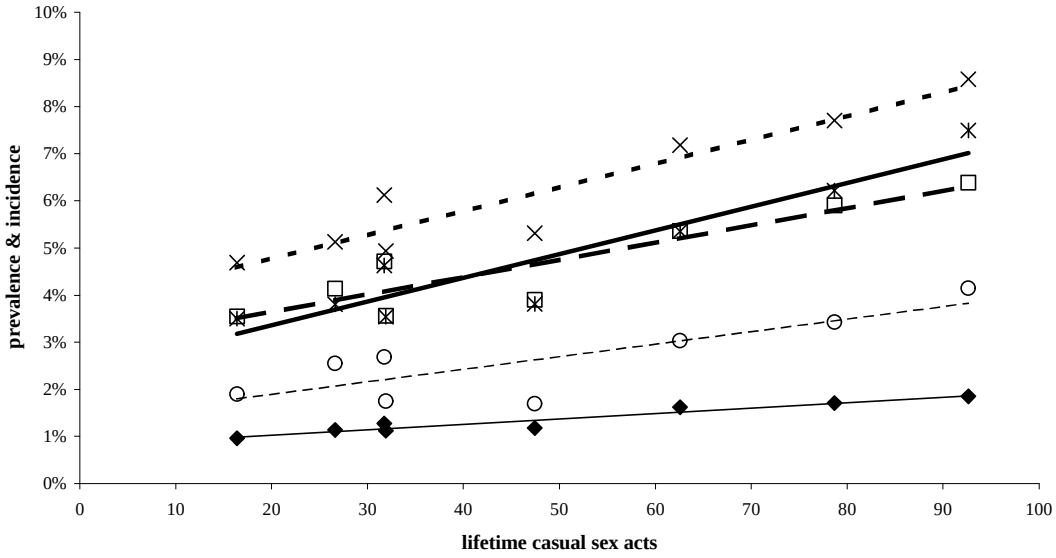


Figure 3b: Condom use in casual and cohabiting partnerships

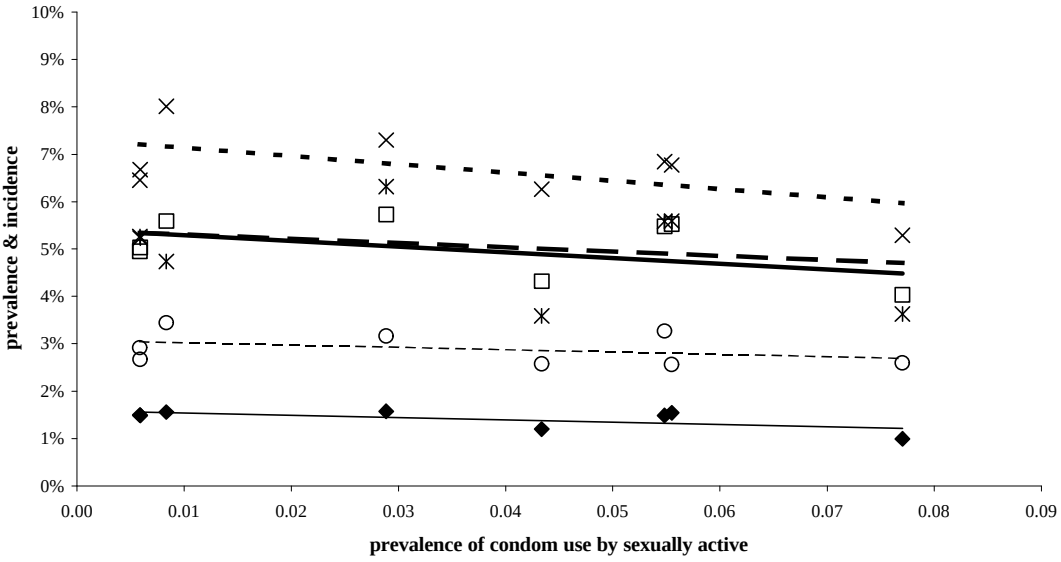


Figure 3c: Co-infection with other STD: episode duration and transmission probability

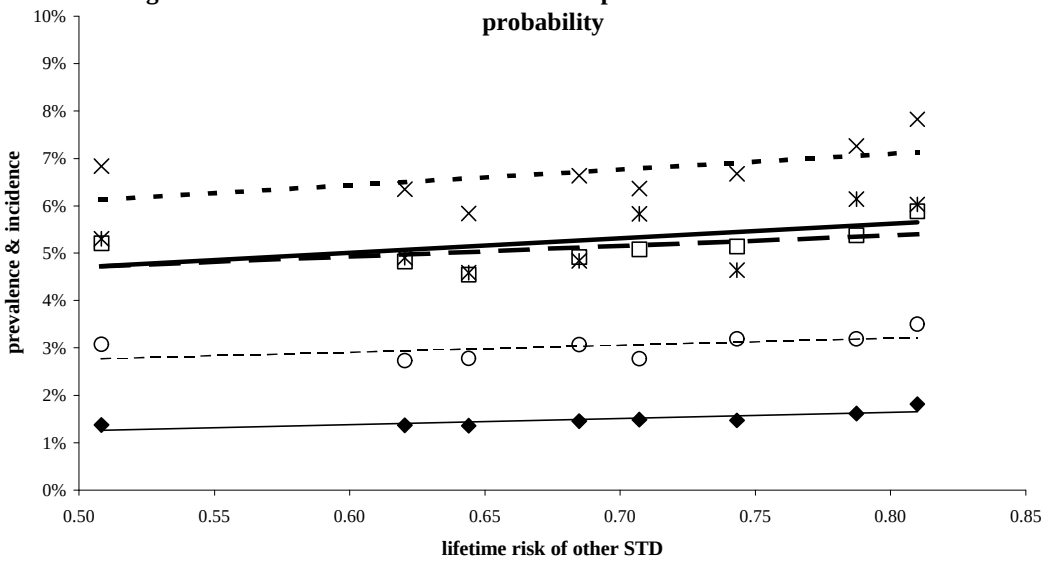
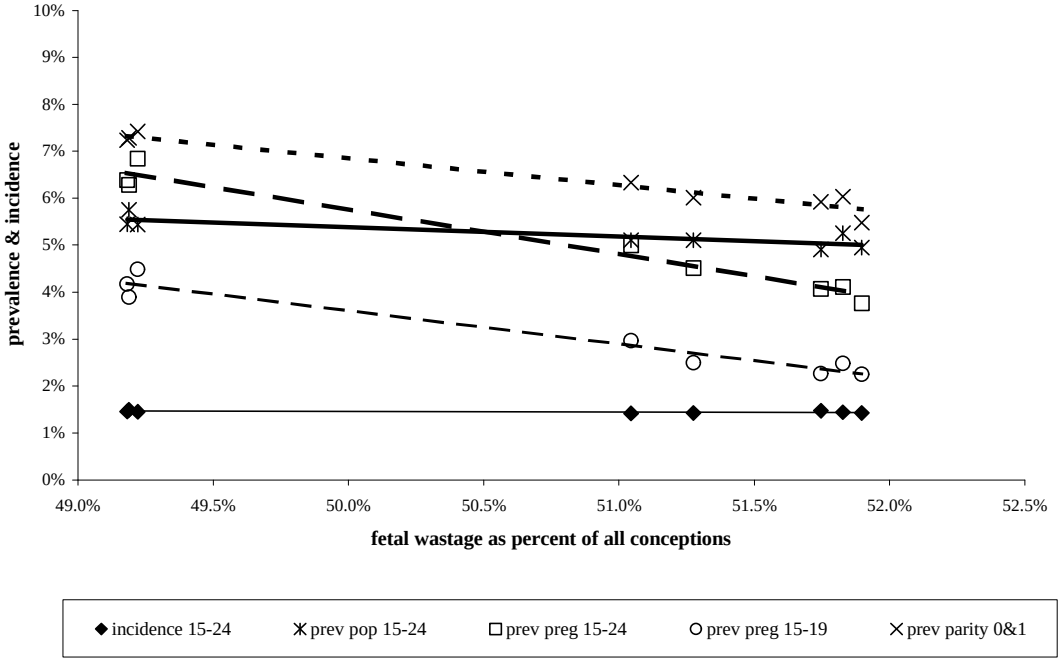


Figure 3d: Fetal loss due to vertical transmission



References

1. Batter, V., B. Matela, M. Nsuami, et al., High HIV-1 incidence in young women masked by stable overall seroprevalence among childbearing women in Kinshasa, Zaire: estimating incidence from serial seroprevalence data. AIDS, 1994. 8(6): p. 811-7.
2. Gregson, S., C.A. Donnelly, C.G. Parker, and R.M. Anderson, Demographic approaches to the estimation of incidence of HIV-1 infection among adults from age-specific prevalence data in stable endemic conditions. AIDS, 1996. 10(14): p. 1689-97.
3. Cleghorn, F.R., N. Jack, J.R. Murphy, et al., Direct and indirect estimates of HIV-1 incidence in a high-prevalence population. Am J Epidemiol, 1998. 147(9): p. 834-9.
4. Saidel, T., D. Sokal, J. Rice, T. Buzingo, and S. Hassig, Validation of a method to estimate age-specific human immunodeficiency virus (HIV) incidence in developing countries using population-based seroprevalence data. Am J Epidemiol, 1996. 144: p. 214-223.
5. US Bureau of Census, HIV/ AIDS Surveillance Data Base, . 1999: Washington.
6. Zaba, B. and S. Gregson, Measuring the impact of HIV on Fertility in Africa. AIDS, 1998. 12(Supplement 1): p. S41-S50.
7. Wawer, M.J., N.K. Sewankambo, S. Berkley, et al., Incidence of HIV-1 infection in a rural region of Uganda. BMJ, 1994. 308(6922): p. 171-3.
8. Taha, T.E., G.A. Dallabetta, D.R. Hoover, et al., Trends of HIV-1 and sexually transmitted diseases among pregnant and postpartum women in urban Malawi. AIDS, 1998. 12(2): p. 197-203.
9. Asiimwe Okiror, G., A.A. Opio, J. Musinguzi, E. Madraa, G. Tembo, and M. Carael, Change in sexual behaviour and decline in HIV infection among young pregnant women in urban Uganda. AIDS, 1997. 11(14): p. 1757-63.
10. Kilian, A.h.D., S. Gregson, B. Ndyanabangi, et al., Reductions in risk behaviour provide the most consistent explanation for declining HIV-1 prevalence in Uganda. AIDS, 1999. 13: p. 391-398.
11. Fontanet, A.L., T. Messele, A. Dejene, et al., Age- and sex-specific HIV-1 prevalence in the urban community setting of Addis Ababa, Ethiopia. AIDS, 1998. 12(3): p. 315-22.
12. WHO, Evaluation of a national AIDS programme. A methods package. 1. Prevention of HIV infection. GPA. WHO/GPA/TCO/SEF/94.1, . 1994: Geneva.
13. UNAIDS/ WHO/ MEASURE Evaluation/ USAID, National AIDS programmes: a guide for monitoring and evaluation, . 1999 Draft: Geneva.
14. Jackson, D.J., E.N. Ngugi, F.A. Plummer, et al., Stable antenatal HIV-1 seroprevalence with high population mobility and marked seroprevalence variation among sentinel sites within Nairobi, Kenya. AIDS, 1999. 13(5): p. 583-9.
15. Lee, L. Fertility reduction and duration of HIV infection: Findings from the United States. in HIV, STD and Infertility conference. Arlingtom, Virginia. 1998. .
16. Makubalo, L., Eighth national seroprevalence survey of women attending antenatal clinics in South Africa. 1997, . 1998, Department of Health: Pretoria, South Africa.
17. Damisoni, H., O. Kaluwa, H. Feluzi, and A. Zingani, HIV/ syphilis seroprevalence in antenatal clinic attenders., . 1997, National AIDS control programme. Sentinel surveillance report: Lilongwe, Malawi.

18. Konde Lule, J.K., M.J. Wawer, N.K. Sewankambo, et al., Adolescents, sexual behaviour and HIV-1 in rural Rakai district, Uganda. AIDS, 1997. 11(6): p. 791-9.
19. Programme National de Lutte contre le SIDA, 1997 Population-based serosurvey, . 1998, Ministry of Health.
20. White, R., B. Zaba, T. Boerma, and J. Blacker, Modelling the dramatic decline of primary sterility in sub-Saharan Africa, in Women and Infertility in Africa: A multidisciplinary perspective, T. Boerma and Z. Mgalla, Editors. 2000-in press, Royal Tropical Institute: Amsterdam.
21. Bunnell, R.E., S. Yanpaisarn, P.H. Kilmarx, et al., HIV-1 seroprevalence among childbearing women in northern Thailand: monitoring a rapidly evolving epidemic. AIDS, 1999. 13(4): p. 509-15.
22. Mulder, D., A. Nunn, A. Kamali, and J. Kengeya Kayondo, Decreasing HIV-1 seroprevalence in young adults in a rural Ugandan cohort. BMJ, 1995. 311(7009): p. 833-6.
23. Wawer, M.J., D. Serwadda, R.H. Gray, et al., Trends in HIV-1 prevalence may not reflect trends in incidence in mature epidemics: data from the Rakai population-based cohort, Uganda. AIDS, 1997. 11(8): p. 1023-30.
24. Nelson, K.E., D.D. Celentano, S. Eiumtrakol, et al., Changes in sexual behavior and a decline in HIV infection among young men in Thailand. N Engl J Med, 1996. 335(5): p. 297-303.
25. Mason, C.J., S. Kitsiripornchai, L.E. Markowitz, et al., Nationwide surveillance of HIV-1 prevalence and subtype in young Thai men. J Acquir Immune Defic Syndr Hum Retrovirol, 1998. 19(2): p. 165-73.
26. UNAIDS, Connecting lower HIV infection rates with changes in sexual behaviour in Thailand: data collection and comparison, . 1998: Geneva.
27. Hanenberg, R.S., W. Rojanapithayakorn, P. Kunasol, and D.C. Sokal, Impact of Thailand's HIV-control programme as indicated by the decline of sexually transmitted diseases. Lancet, 1994. 344(8917): p. 243-5.
28. Fylkesnes, K., Z. Ndhlovu, K. Kasumba, R. Mubanga Musonda, and M. Sichone, Studying dynamics of the HIV epidemic: population-based data compared with sentinel surveillance in Zambia. AIDS, 1998. 12(10): p. 1227-34.
29. Sokal, D.C., T. Buzingo, N. Nitunga, P. Kadende, and B. Standaert, Geographic and temporal stability of HIV seroprevalence among pregnant women in Bujumbura, Burundi. AIDS, 1993. 7(11): p. 1481-4.
30. Chao, A., M. Bulterys, F. Musanganire, et al., Risk factors associated with prevalent HIV-1 infection among pregnant women in Rwanda. National University of Rwanda-Johns Hopkins University AIDS Research Team. Int J Epidemiol, 1994. 23(2): p. 371-80.
31. Slutsker, L., J. Cabeza, J.J. Wirima, and R.W. Steketee, HIV-1 infection among women of reproductive age in a rural district in Malawi. AIDS, 1994. 8(9): p. 1337-40.
32. Boerma, J.T., M. Urassa, K. Senkoro, A. Klokke, and J.Z.L. Ng'weshemi, Spread of HIV infection in a rural area in Tanzania. AIDS, 1999. 13: p. 1233-1240.
33. Shao, J., G. Brubaker, A. Levin, et al., Population-based study of HIV-1 infection in 4,086 subjects in Northwest Tanzania. J.Acq.Imm.Def.Syndr., 1994. 7: p. 397-402.

34. Kapiga, S.H., E.F. Lyamuya, G.K. Lwihula, and D.J. Hunter, The incidence of HIV infection among women using family planning methods in Dar es Salaam, Tanzania. AIDS, 1998. 12: p. 75-84.
35. Leroy, V., P. Van de Perre, P. Lepage, et al., Seroincidence of HIV-1 infection in African women of reproductive age: a prospective cohort study in Kigali, Rwanda, 1988-1992. AIDS, 1994. 8(7): p. 983-6.
36. Kengeya Kayondo, J.F., A. Kamali, A.J. Nunn, A. Ruberantwari, H.U. Wagner, and D.W. Mulder, Incidence of HIV-1 infection in adults and socio-demographic characteristics of seroconverters in a rural population in Uganda: 1990-1994. Int J Epidemiol, 1996. 25(5): p. 1077-82.